FERMILAB-UPC-151

TWIST PROPERTIES OF CURRENT ENERGY SAVER DIPOLES AND OF A MODIFIED YOKE

H.Jöstlein and J.Raczek

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INTRODUCTION

We have measured the twist/torque characteristics of a complete dipole (#414) and of a yoke modified by welding a 4¼" × ¼" steel plate to each side for the full length of the yoke (except for two 4" gaps where the surveying lugs are). These side plates connect the top and bottom angles as seen in Fig. 1.

EXPERIMENTAL SET-UP

For the twist measurements, the yoke was supported on two beams (see Fig. 2) at the standard support positions. One of the beams is supported near the ends. The other has a single movable support, initially located at the center, which can be moved in 1½" increments to induce a twist into the yoke by using its own weight to provide the twisting torque. This set-up was originally built by Hartwig Kaiser and since has also been used by J.Raczek (see references).

One inclinometer made from a micrometer and a sensitive bubble level was mounted near each support (on the side away from the magnet center) as indicated in Fig. 2. The yoke twist is the angular difference between these two inclinometer readings. The zero of the twist was arbitrarily taken as the twist recorded for zero torque on e "relaxed" yoke (see below).

PROCEDURE

Since the torque history of a given yoke or magnet is unknown, each is first relaxed by applying alternating sign torques of decreasing magnitude to it.

After the relaxation, each item was torqued in one direction from zero to successively larger torques, with a data point taken at zero torque between steps. This measurement yields data on torsional stiffness as well as permanent deformation as a function of torque.

RESULTS

a. Current Production Dipole (#414)

Figure 3 shows a plot of twist versus torque for magnet #414 during relaxation. Measurements were made for a torque of 12" × weight/2 = 4200 ft-lbs for three complete cycles of alternating sign. The magnet started out at point A and settled in a fat hysteresis loop about zero.

When the torque was reduced on successive cycles, the hysteresis loop became much slimmer; i.e., more nearly elastic.

Figure 4 shows the behavior of the same magnet when the torque was increased in 3" steps in the same direction, always taking a zero torque reading between steps. The open circles show the twist while torque is applied, the full circles the remaining twist at zero torque (plotted at the largest torque applied previously).

b. Modified Yoke

Similar measurements were made on the modified yoke (Fig. 1). This was not a complete magnet, hence its weight and the torque applied for a given distance of support was approximately 15% lower.

Figure 5 shows all the data taken with this yoke. During relaxation, no data were taken at zero torque. The data at the (alternating sign) torque maxima are shown as full circles. Data taken during the phase where same sign increasing torques were applied are shown as open triangles. They agree completely with the readings taken during relaxation.

The resulting twist/torque curves show linear behavior up to a torque of ±20". The remaining (inelastic) deformation is roughly linear with torque, and much smaller than for the standard yoke, at least at large torque. The torsional stiffness is similar for the two yokes for small torques (less than 6"); at large torque the modified ɔke is much stiffer than the standard yoke, since it does not show the "softening" seen with the standard yoke at large torque. This "softening" may well indicate frictional slippage of laminations on one another within the stack, consistent with the large remaining deformations seen on the standard yoke.

The open box point is the result of a calculation for a hollow continuous box beam of ¼" wall thickness. It agrees well with the measurements indicating that most of the stiffness comes from the skin not the laminations.

DISCUSSION

We need to compare the results shown in Figs. 3, 4, 5 to the torques that may be applied to magnets during transportation and installation.

One magnet on its tunnel stands will experience a torque of 4.5" (= 3200 ft-lbs) since the stands are 4.5" apart. During installation higher g-values may occur increasing the torque.

Transportation is done on three-point stands, which should eliminate large torques.

Stacks of magnets, four high, can create torques due to misalignment of supports and the natural width of the aluminum shims on the stands. A maximum of ½" misalignment and 1" half-width causes 4 × 1.5" = 6" of torque. If the top magnet is set down a little roughly this may be exceeded.

A magnet supported by nylon slings may experience no more than 7.5" of torque.

It should be noted that the twist appears as soon as the torque is applied (i.e., within one minute). We have found no evidence for creep.

Significant permanent deformation occurs in the standard yoke for torques exceeding 10". Such torques should not occur during normal handling, although there is not a large safety factor.

ARE THE SIDE PLATES PRACTICAL?

They do not interfere with any production, surveying, or installation step. In order to accommodate the hydraulic pistons of the sagitta table the edges of the side plates should be scalloped. On our model yoke, the welds were left off in those areas to simulate the loss of strength. The side plates could be welded to the half-yokes, possibly omitting the present welds from the angles to the laminations (or reducing their length).

ACKNOWLEDGEMENT

We are grateful to J.Carson for the welding of the special yoke. D.Gross lent us his inclinometer (and fixed it).

REFERENCES

Hartwig Kaiser: Twist Characteristics of Energy Doubler Dipole, November 13, 1979 (draft).

J.D.Raczek: Twist and Bending Characteristics of Modified 200 Series Dipole Yoke, April 2, 1980.

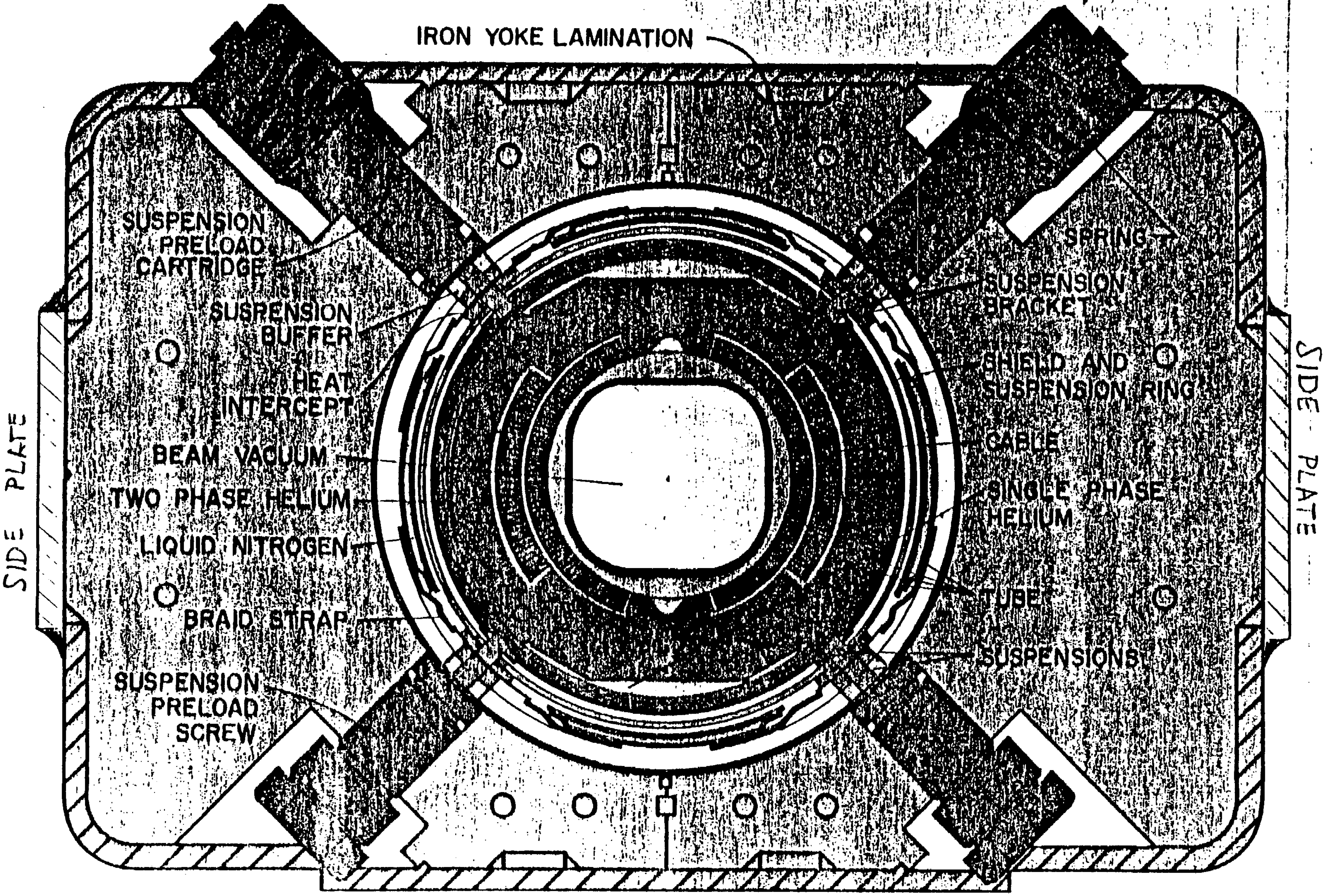

FIG. 1 YOKE MODIFICATION

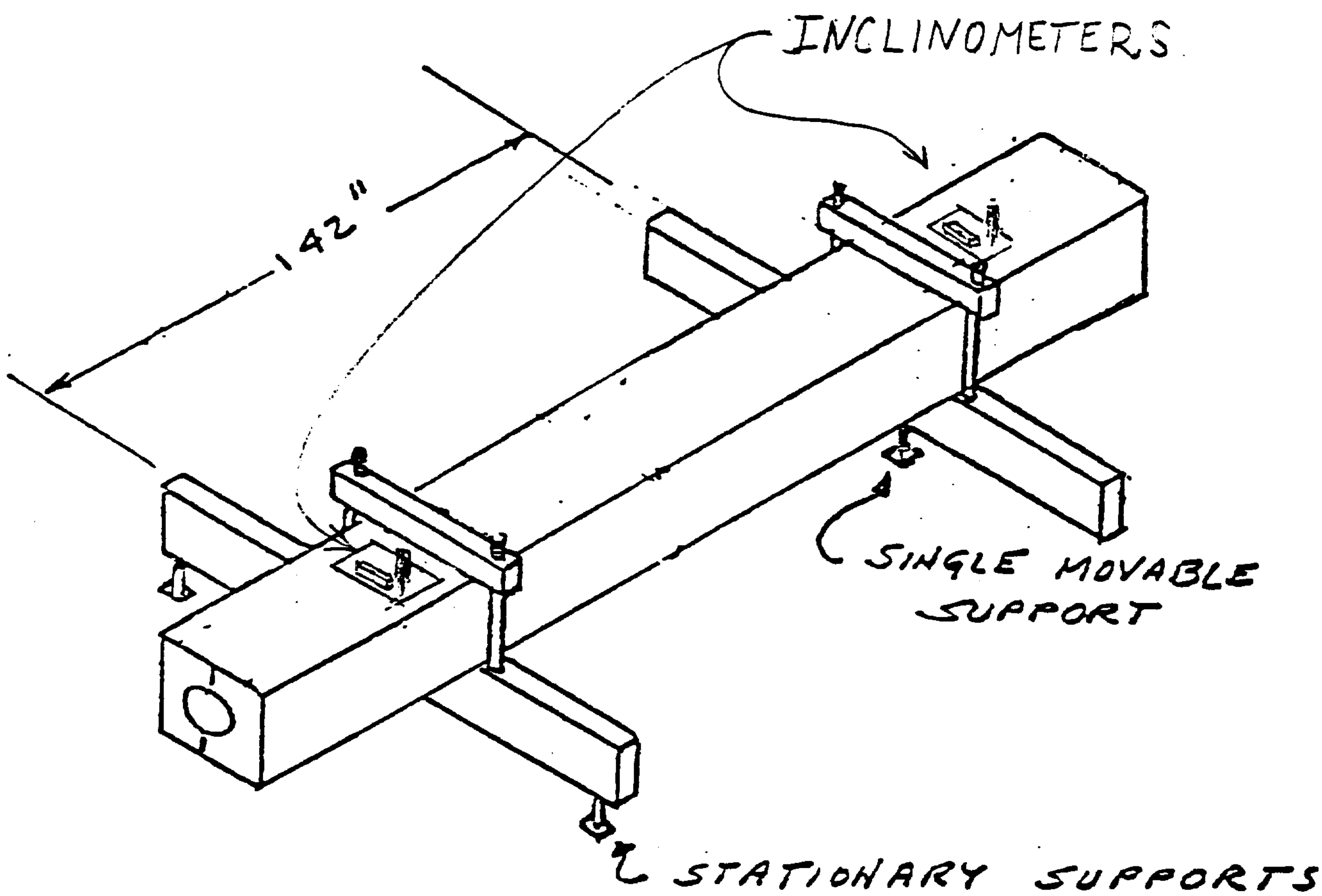

FIG. 2 TWIST MEASUREMENT

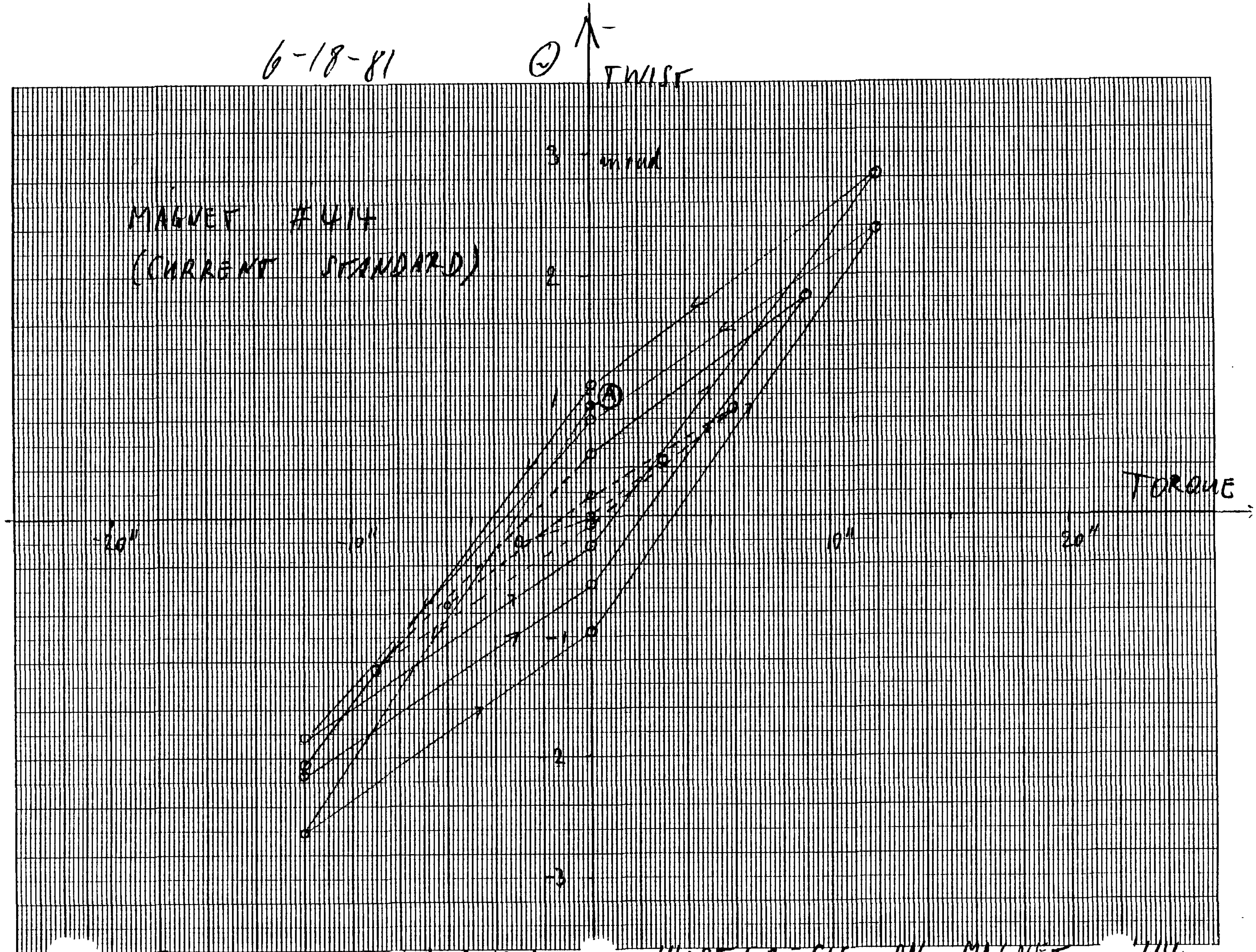

FIG. 3 RELAXATION & HYSTERESIS ON MAGNET 414

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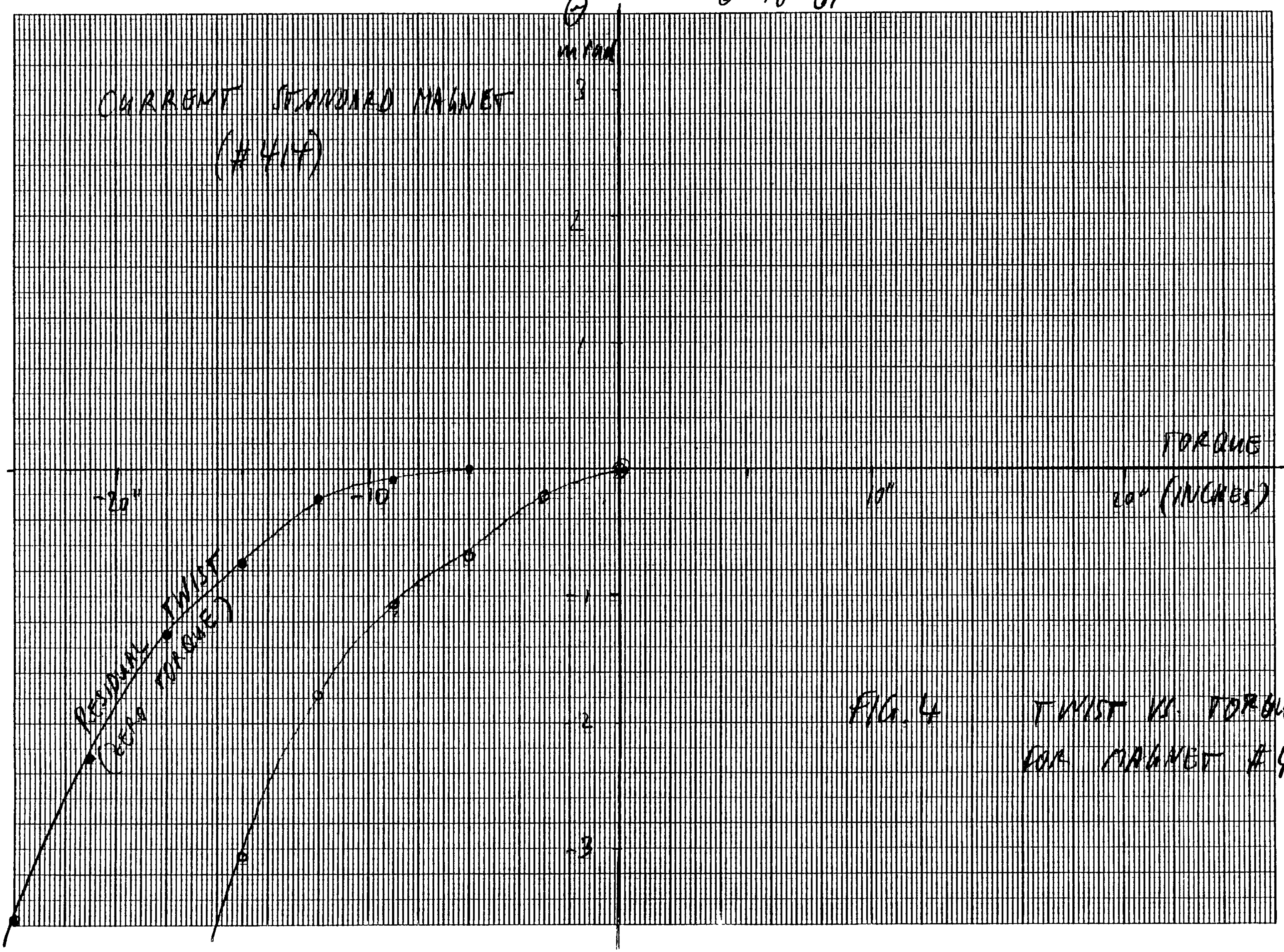
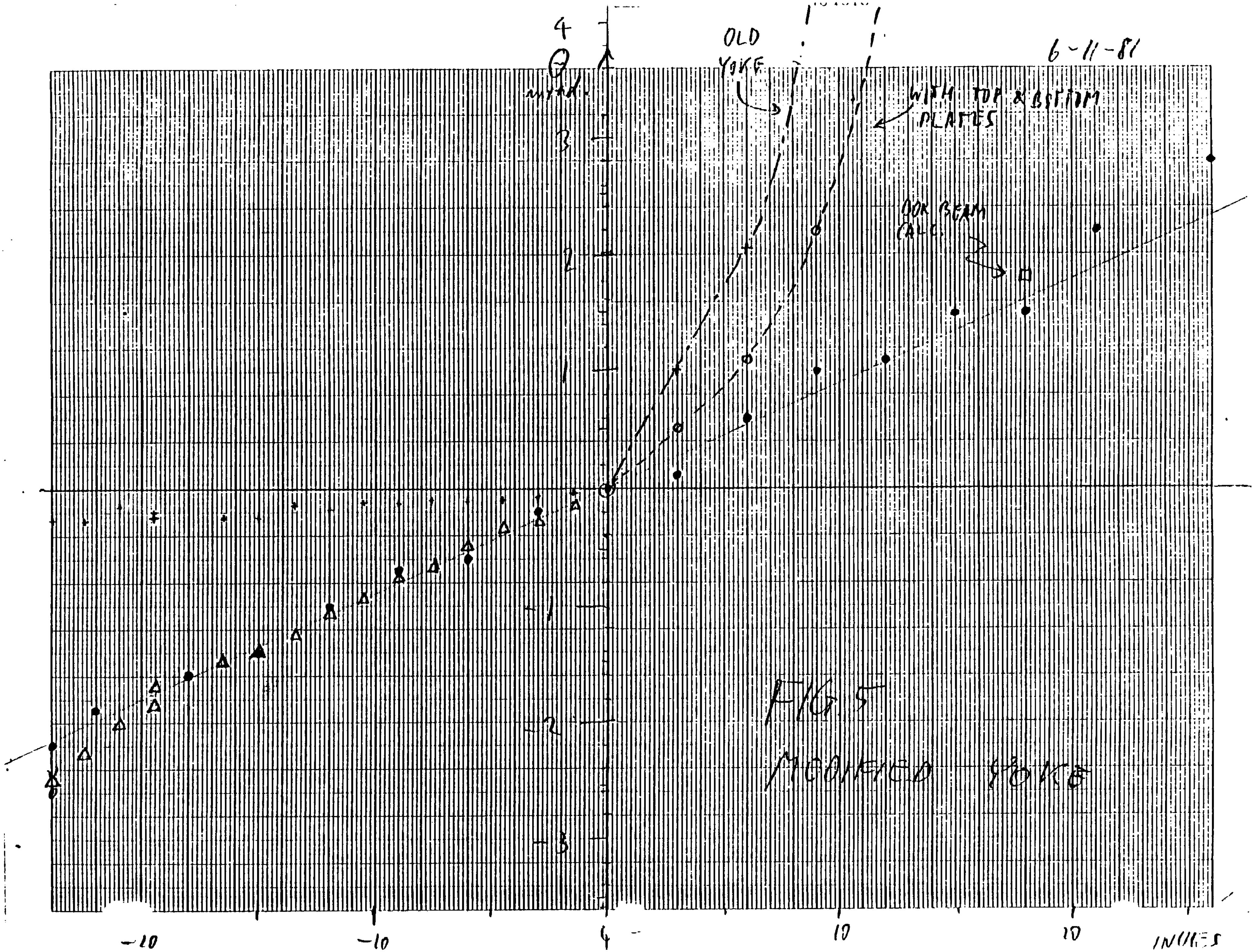


FIG. 4 TWIST VS. TORQUE FOR MAGNET #414



4
θ
mrad.
3
2
1
-1
-2
-3
OLD YOKE
WITH TOP & BOTTOM PLATES
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OOK BEAM CALC.
FIG 5
MODIFIED YOKE
-20
-10
0
10
10
INCHES